AD-A145 433

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1a. REPORT SECURITY CLASSIFICATION	1b. RESTRICTIVE MARKINGS
Unclassified	N/A

2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT
N/A	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	Unlimited
N/A	

4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
N/A	N/A

6a. NAME OF PERFORMING ORGANIZATION	6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
Defense Mapping Agency Aerospace Center	CDIT	N/A

6c. ADDRESS (City, State and ZIP Code)	7b. ADDRESS (City, State and ZIP Code)
St. Louis AFS, MO 63118	N/A SEP 1 3 1984

8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
N/A	N/A	N/A

8c. ADDRESS (City, State and ZIP Code)	10. SOURCE OF FUNDING NOS.			
	PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
N/A	N/A			

11. TITLE (Include Security Classification)
Digital Terrain Elevation Data (DTED) (over)

12. PERSONAL AUTHOR(S)
Mr. Richard L. Fortson

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
Interim	FROM 1983 TO 1984	1984 July 2	32

16. SUPPLEMENTARY NOTATION
N/A

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB. GR.	Digital Terrain, DTED, Filtering

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The Defense Mapping Agency is a producer of raster formatted elevation data in a form called DTED (Digital Terrain Elevation Data). This data is collected from digitized source maps and from optically or digitally correlated stereopairs of photographic imagery. The various means used in producing DTED sometimes introduce a striation anomaly into the data. Conventional techniques for handling this anomaly have included the use of convolution with smoothing filters. Smoothing, however, degrades the high quality resolution of the data. A more precise method specific only to the anomaly was required. To accomplish this, an interactive Fourier frequency filtering program was designed to allow analysis and filtering of the DTED in the frequency domain. The process allows the analyst to use the data's amplitude spectrum as an aid in designing an area specific low-pass, band-reject, or fan-reject filter. This technique can result in almost total elimination of the striation anomaly with virtually no degradation of the high quality resolution of the data.

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20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐	Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE NUMBER (Include Area Code)	22c. OFFICE SYMBOL
Mr. Richard L. Fortson	314/263-4339	CDIT

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(continued).

Anomaly Removal Through the Use of an Interactive Fourier Frequency Filtering Process.

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DIGITAL TERRAIN ELEVATION DATA (DTED) ANOMALY REMOVAL THROUGH

THE USE OF AN INTERACTIVE FOURIER FREQUENCY FILTERING PROCESS

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ABSTRACT

The Defense Mapping Agency is a producer of raster formatted elevation data in a form called DTED (Digital Terrain Elevation Data). This data is collected from digitized source maps and from optically or digitally correlated stereo-pairs of photographic imagery. The various means used in producing DTED sometimes introduce a striation anomaly into the data. Conventional techniques for handling this anomaly have included the use of convolution with smoothing filters. Smoothing, however, degrades the high quality resolution of the data. A more precise method specific only to the anomaly was required. To accomplish this, an interactive Fourier frequency filtering program was designed to allow analysis and filtering of the DTED in the frequency domain. The process allows the analyst to use the data's amplitude spectrum as an aid in designing an area specific low-pass, band-reject, or fan-reject filter. This technique can result in almost total elimination of the striation anomaly with virtually no degradation of the high quality resolution of the data.

INTRODUCTION

The Defense Mapping Agency produces digital cartographic data bases that are used in describing the physical appearance of the earth's surface. This data includes terrain elevation in a raster format called Digital Terrain Elevation Data (DTED). This basic terrain data is provided in one degree by one degree units called cells with cell elevation post spacings that can vary, depending on the cell's latitude. The data is collected from digitized source maps and from optically or digitally correlated stereo-pairs of photographic imagery. Sometimes, the means used in producing the cells can introduce anomalies into the data. One type of anomaly consists of a machine-induced striation effect that is superimposed upon the real data (see Fig 1). It is a low level amplitude near-sinusoidal high frequency undulation whose visual appearance in the data is almost that of a plowed field. Conventional techniques for handling this anomaly have included the use of convolution with smoothing filters. Smoothing, however, degrades the high quality resolution of the data. A more precise method, specific only to the anomaly, was required. To accomplish this, an interactive Fourier frequency filtering process was designed to allow analysis and filtering of the data in the frequency domain. This process allows the analyst to use the data's amplitude spectrum as an aid in designing a cell specific low-pass, band-reject or fan-reject filter. The technique can result in almost total elimination of the striation anomaly with virtually no degradation to the quality of the elevation data.

The images that are shown in this report were created using the Sensor Image Simulator (SIS) system. The SIS is a near real-time processing system used for the analysis and exploitation of digital terrain and feature data produced by the Defense Mapping Agency[1].

CONCEPTS

Before explaining in detail the process used, it may be helpful to review some of the Fourier analysis concepts used in this technique.

Each cell of elevation data, though existing in the spatial domain in the DTED format, has an associated frequency domain aspect. The key to transforming the data between the spatial and frequency domains is the Fourier transform[2,3]. The integral expression for the Fourier transform is expressed in two forms, one for the frequency spectrum F(s) in terms of a spatial function f(x) and the other for the spatial function in terms of the frequency spectrum. The frequency function F(s) can be obtained from a one-dimensional spatial function by the use of the integral:

$$F(s) = \int_{-\infty}^{+\infty} f(x) \cos(2\pi sx)dx - i \int_{-\infty}^{+\infty} f(x) \sin(2\pi sx)dx \qquad (1)$$

The spatial variable is designated by x and frequency by s.

Similarly, the transform of the frequency function F(s) can be expressed by the integral:

$$f(x) = \int_{-\infty}^{+\infty} F(s) \cos(2\pi sx)ds - i \int_{-\infty}^{+\infty} F(s) \sin(2\pi sx)ds \qquad (2)$$

The integral containing the cosine term is designated as real, while that containing the sine term is designated as imaginary; hence the use of the coefficient "i". This complex representation is a mathematical convenience, as the two terms cannot be added directly but must be added vectorially, the sum having a magnitude and phase angle for each frequency which can be determined by following the rules for addition of complex quantities.

Designating the cosine integral in Eq. (1) as C(s) and the sine integral as S(s), we can show that the amplitude A(s) of the spectrum at frequency s is:

$$A(s) = \sqrt{C(s)^2 + S(s)^2} \qquad (3)$$

and the phase angle, also a function of frequency, is:

$$\phi(s) = \tan^{-1} \frac{S(s)}{C(s)} \qquad (4)$$

The computation of Fourier transforms is simplified for functions that are symetric about their respective axes. With such functions, the imaginary sine term of the transform disappears because in the integration between $-\infty$ and $+\infty$ each positive product on the right side of the axis is cancelled by an equal negative product the same distance on the left side.

THE METHOD

Discrete methods (such as the "Fast Fourier Transform" or FFT) are available for doing these transforms in two dimensions. DTED cells generally come in a matrix size of 1201 by 1201, 601, or 401. Since these discrete methods

require an input matrix of size n^2, where n is a power of two, the cell must first be re-rastered to a size n^2 before being input into the FFT processing. The raster size chosen for this process is 1024 by 1024.

The discrete transforms are equivalent to a Fourier series expansion. We will, therefore, treat the cell of DTED data as though it were a period of a two-dimensional periodic function as shown in Fig. 2. When viewed as a periodic function, differences in elevation values on opposite edges of the cell create discontinuities in the periodic function. The existence of these discontinuties contributes high frequency energy in the transform domain (see Fig. 3). To prevent the warped spectrum caused by the discontinuities in the periodic functions and at the same time guarantee that phase information is preserved exactly, the cell is made evenly symetric by folding over the data into three quadrants (see Fig. 4a). Because the transform of a function which is evenly symmetric in both directions produces coefficients which are pure real and equal in all quadrants, the phase is zero and need not be considered. In addition, the redundancy in the cell's spectrum allows a reduction in the amount of data that need be stored.

Once the amplitude spectrum is computed, it is displayed onto a high resolution color monitor. The spectrum can have its values color mapped according to a logical color scale (from violet to green to red) so that the analyst can use it to design a cell-specific frequency filter. A cursor is used to center the filter onto a specific band of frequencies. The options for filter designs include exponential, Buttersworth, and fan filters. The frequencies under the filter can be eliminated or reduced in energy by the point by point multiplication of the filter with the cell's frequency spectrum. Having modified the cell's frequency spectrum, an inverse Fourier transform is performed to take the modified frequency spectrum back to the spatial domain. Once the data is back in the spatial domain, it can be checked for quantitization noise (seen in water bodies) and if desired, a "safety net" program can be run to make sure that the modified cell data does not deviate from the original data by more than a specified amount. Finally, a re-rasterization is done to convert the data back into its original size.

The striation anomaly is readably identifiable in the amplitude spectra of the cells. It consists of one or more bright regions in the higher frequencies along a radial line existing from the spectrum's origin. This radial line runs perpendicular to the orientation of the striations seen in the cells. In addition, the radial line is sometimes visible and seen to run through the high frequency bright regions and downward towards the spectrum's origin.

One simple model for the striation anomaly's appearance in the frequency data is a series of rectangular ridges in the spatial domain. The transform of these ridges is the "sinc function" (see Fig. 4b). Another simple model of the striation anomaly is that of a pure sinusoidal pattern in the spatial domain. Its transform would consist of impulses at the sinusoid's frequency. The actual frequency of the striations seen in the spectra displays can differ somewhat from cell to cell, but generally exhibit both these aspects to some degree.

RESULTS

AREA 1:

Fig. 5 shows a cell of DTED using shaded relief processing with the sun positioned to the northwest. In Fig. 6 and 7, its amplitude spectrum is shown in linear and logarithmic fashion. The striation anomaly is clearly visible in the spectrum as an elongated bright region in the higher frequencies.

A weak radial line is seen to be going through the bright region and down towards the spectrum's origin. The filter chosen for this cell was a moderate exponential low-pass filter (to slightly reduce high frequency random noise) along with a 43 degree fan-reject filter centered along the radial line. A color intensity mapping of this filter is shown in Fig. 8. The effects of quantitization noise in the filtered data can be seen in the large lake at the top of the image in Fig. 9. Here, a color shaded relief image was used to help highlight the lake's relief. The blue lines in the lake identify boundaries where the elevation has changed by one meter. As water bodies are by nature absolutely flat, this quantitization effect on areas of water bodies must be remedied. In Fig. 10, a shaded relief of the filtered data with the quantitization noise removed is shown. The amplitude spectrum of the modified cell can be seen in Fig. 11. Note that the filter has removed the undesired frequencies.

AREA 2:

An image on the original data's shaded relief is shown along with its linear and logarithmic amplitude spectrum in Fig. 12, 13, and 14. This cell's spectrum exhibits a fairly strong radial line. The filter used on the spectrum was a +4 degree fan-reject filter which is shown in Fig. 15. The modified cell is shown as a shaded relief image in Fig. 16. For this modified cell, a "safety net" program was run that allowed a factor of +6 meters difference from the original data. The necessity of this "safety net" feature can be seen in the enlarged color mapping of the grey level difference image in Fig. 17. A steep sided stream was present in the data at an orientation that aligned with that of the spatial striations and fan filter. Removal of some frequencies along the filter that were used in the stream bank's construction has resulted in the spatial elements along the bank's steep slope showing a change of up to 17 meters from the original data. By running a "safety net" program, any removal of real data, such as the data in this example, can be minimized. In Fig. 18, a side by side comparison using shaded relief processing is shown between the original and modified data. In Fig. 19 and 20, anomaly removal through convolution with a smoothing filter of size three by three and five by five is shown. Smoothing has destroyed much of the data's high resolution, as can be seen in these images.

AREA 3:

The shaded relief of a cell containing sand dunes is shown in Fig. 21 and its linear and logarithmic amplitude spectrums in Fig. 22 and 23. This spectrum shows several bright regions along a radial line. Since the anomaly seems confined mostly to these small bright regions, a series of exponential band-reject filters were centered on these points. Fig. 24 demonstrates the outlines of these filters superimposed on the spectrum. The modified cell's shaded relief image is shown in Fig. 25 and the grey level difference with the

original data in Fig. 26. The striations seen in the difference image are typically around 4 meters in amplitude. An interesting geomorphic aspect of the original data can be seen in the linear amplitude spectrum in Fig. 27. A selection of different colors was used to highlight the spectrum. The almost regularly spaced, uniform orientated sand dunes in the data show up distinctly in the spectrum as the second bright yellow area offset from the origin.

CONCLUSION

Precise frequency filtering of DTED in the frequency domain has been demonstrated to offer much promise in the removal of striation anomalies while leaving the high resolution of data intact. In certain areas, the geomorphology can cause problems in regard to the frequencies suppressed. In these cases, a "safety net" option insures the data's integrity after filtering. It is hoped that, in the future, additional types of data anomalies may also lend themselves to this technique.

REFERENCES

1. Faintich, M.B., Figura, P.C.; Quinn, E.W.; 1981; "The Sensor Image Simulator," Proceedings of the Third Interservice/Industry Training Equipment Conference, Orlando, Florida, November 1981, pp. 386-390.

2. Bracewell, R., 1965, The Fourier Transform and Its Applications, McGraw-Hill, New York.

3. Gaskill, J.D., 1978, Linear Systems, Fourier Transforms, and Optics, John Wiley & Sons, New York.
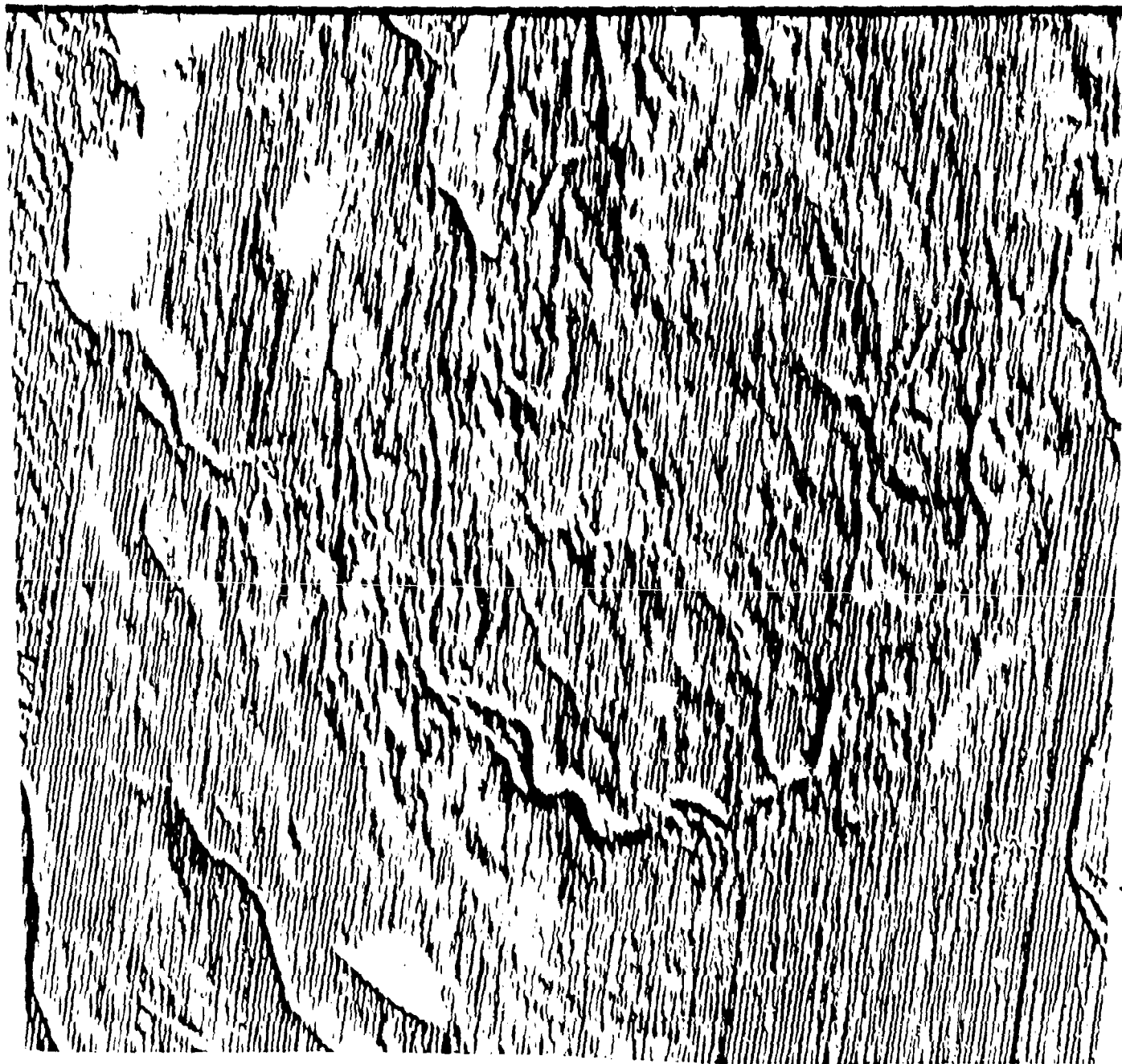
Fig. 1 Shaded Relief of DTED Cell
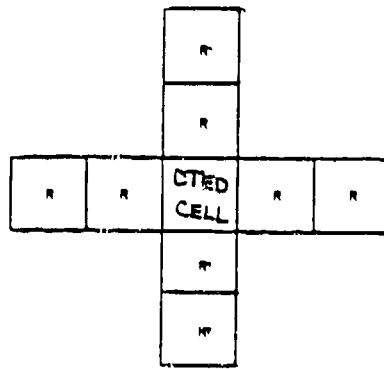
Figure 2   R is repetitive of the cell being transformed.
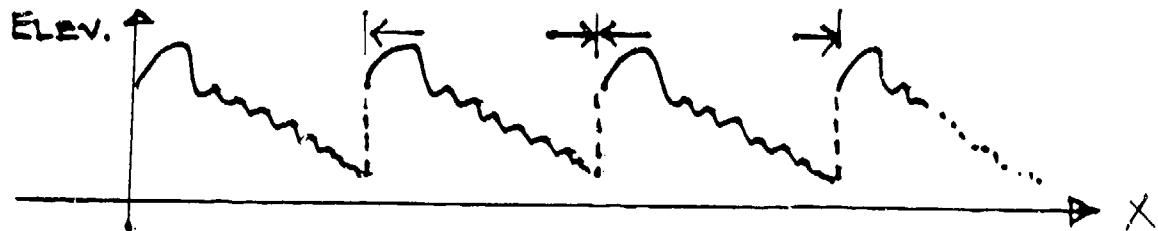
Figure 3   Discontinuities in the periodic structure contribute
                  high frequency energy.
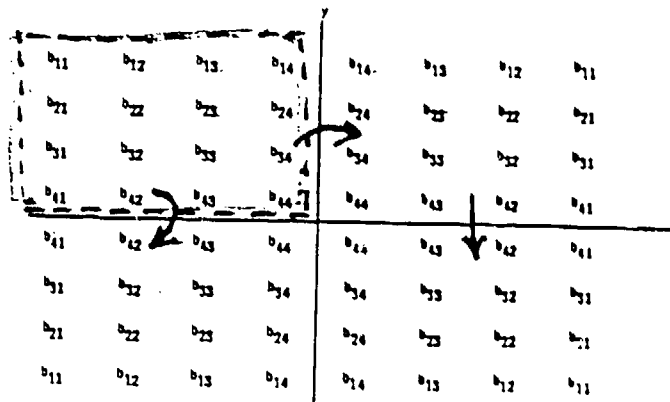
Figure 4a   Evenly symmetric matrix constructed by folding
                  original cell.
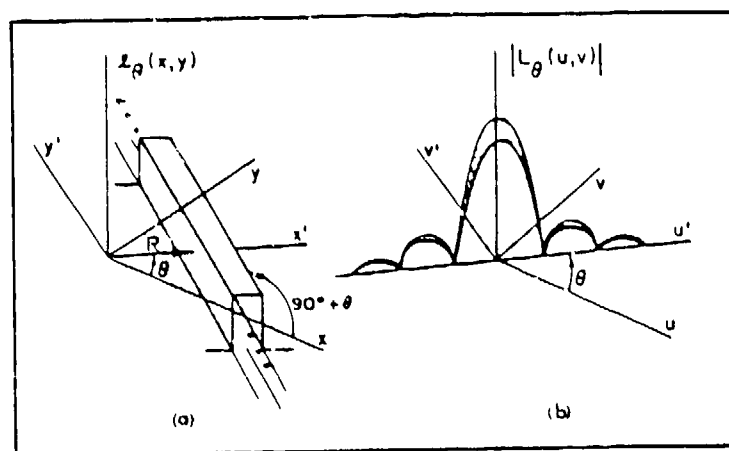
Figure 4b   General line model: (a) the rectangular ridge, and (b) its Fourier transform

Fig. 5 Shaded Relief – Area 1 – Original Data
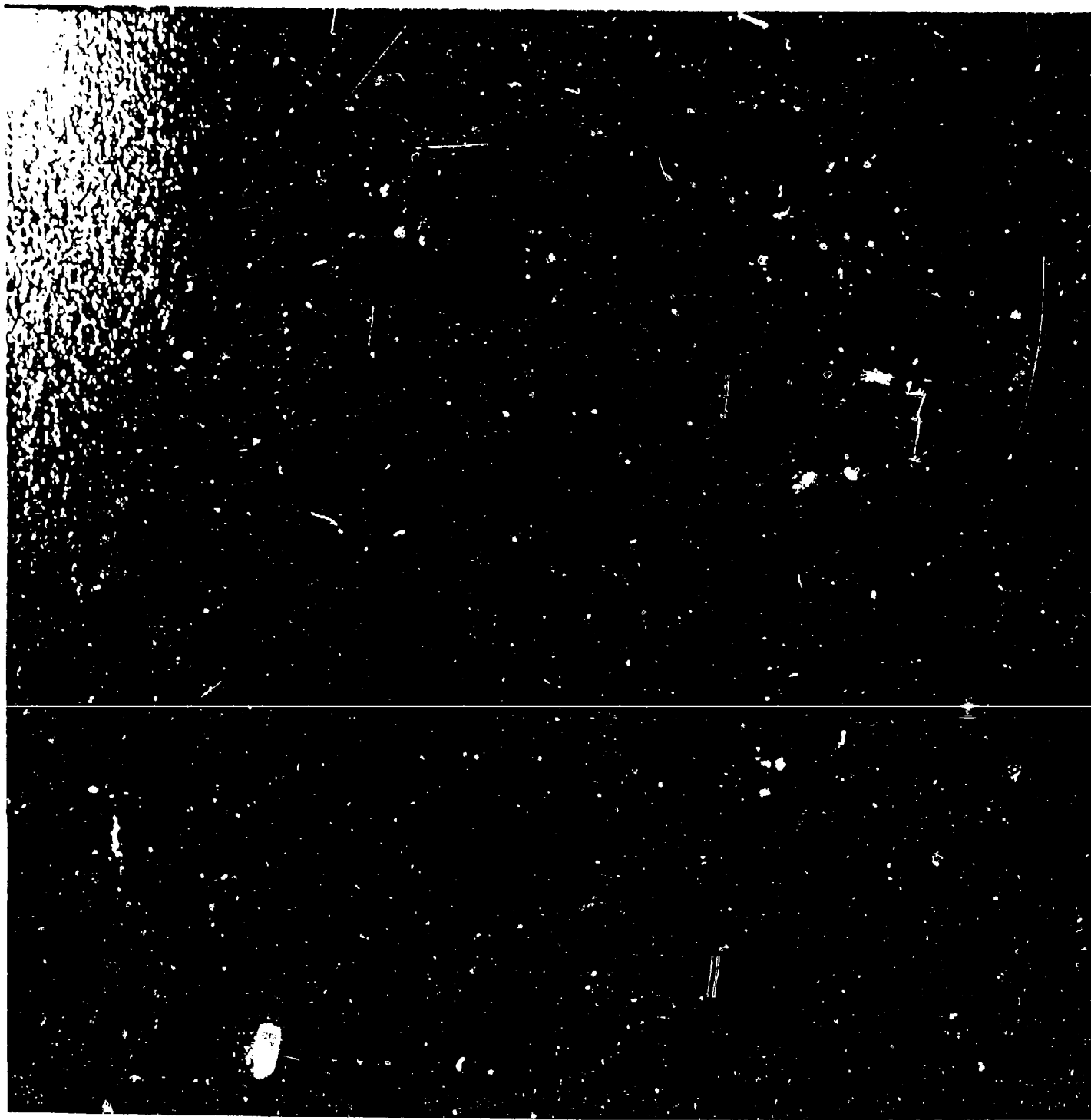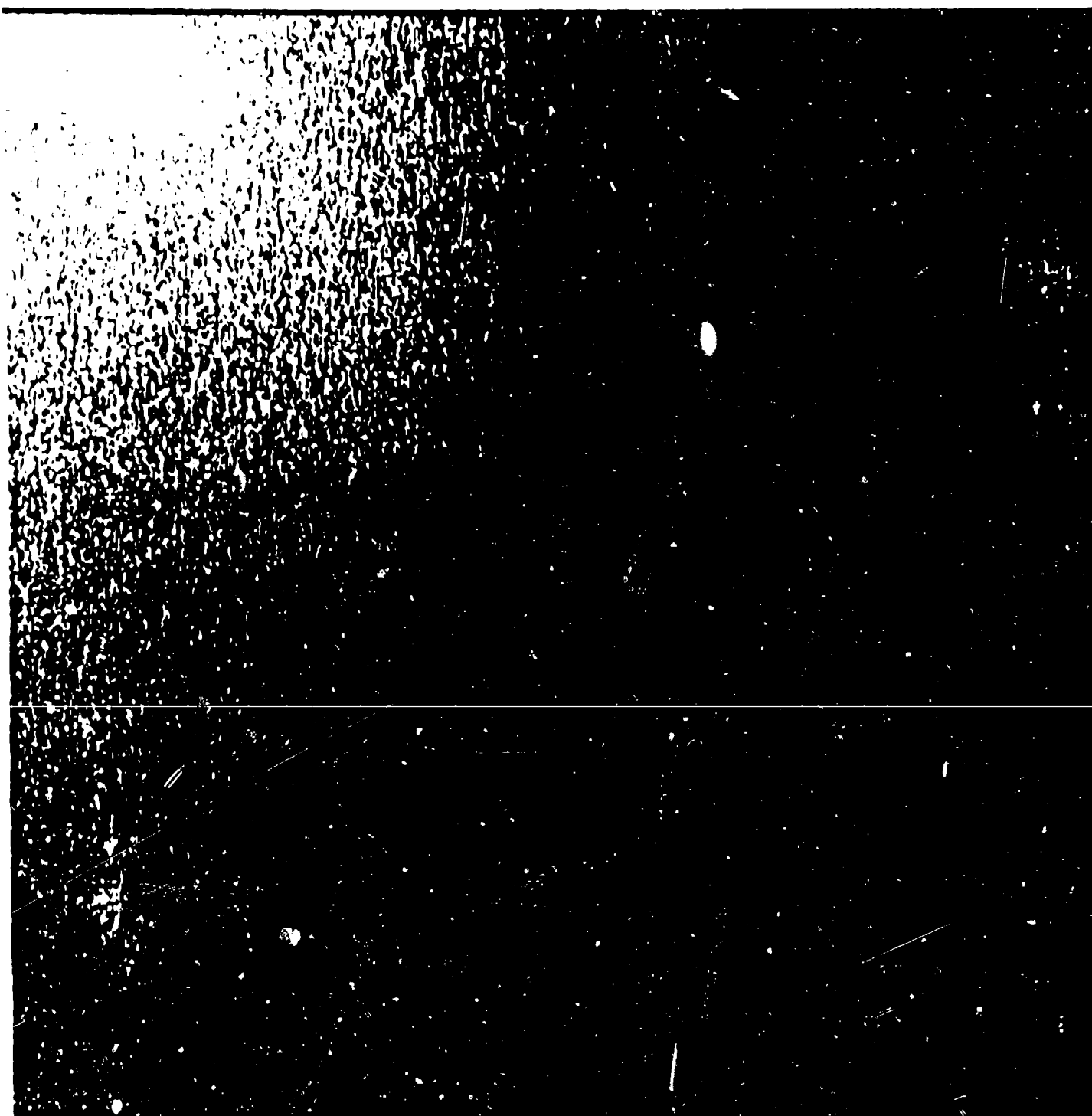
Fig. 6 Linear Spectrum - Area 1 - Original Data
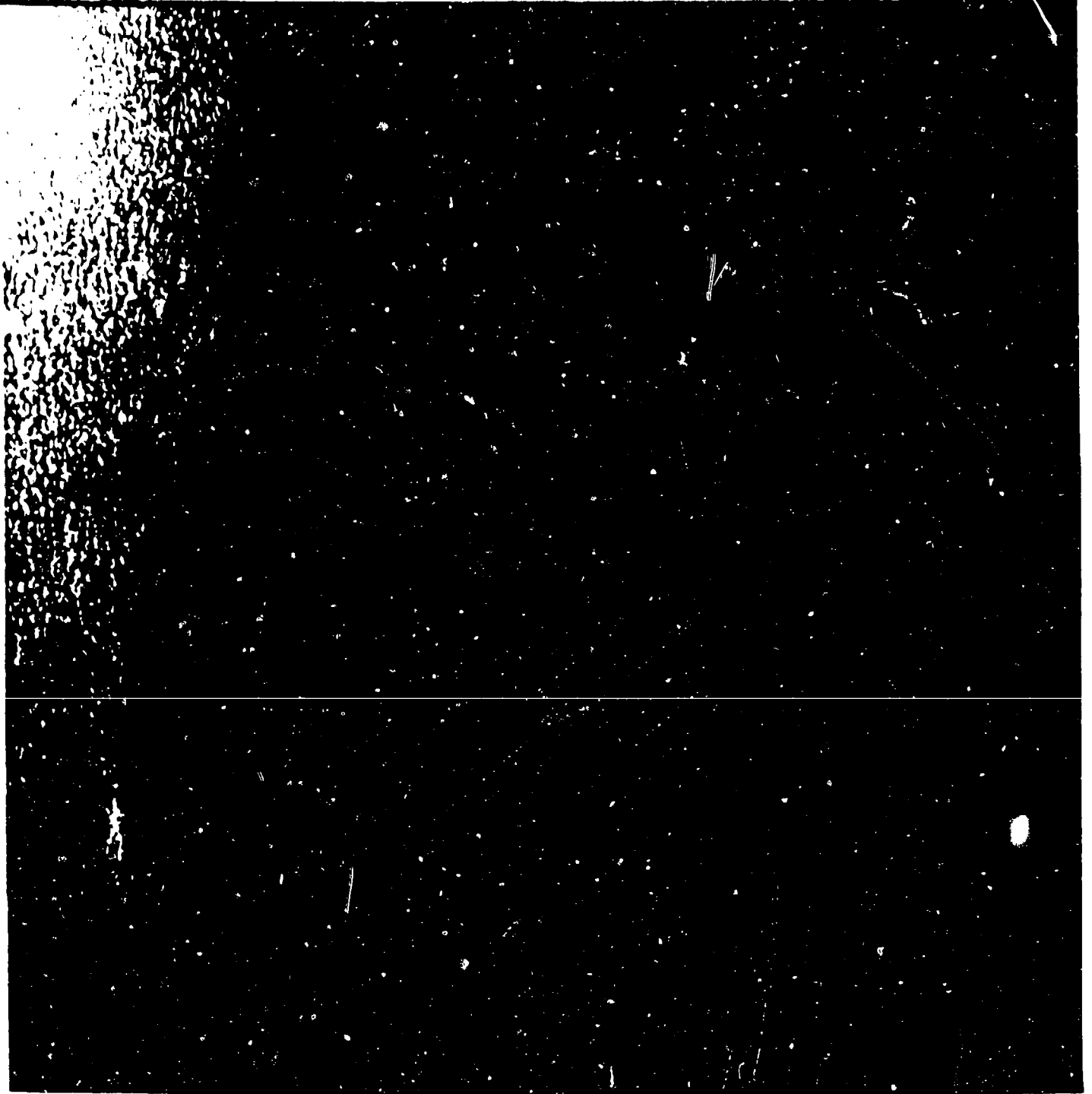
Fig. 7 Log Spectrum – Area 1 – Original Data

Fig. 8 Exponential Lo-pass and ± 3° Fan-reject Filter

Fig. 9 Quantitization Noise in Water Bodies
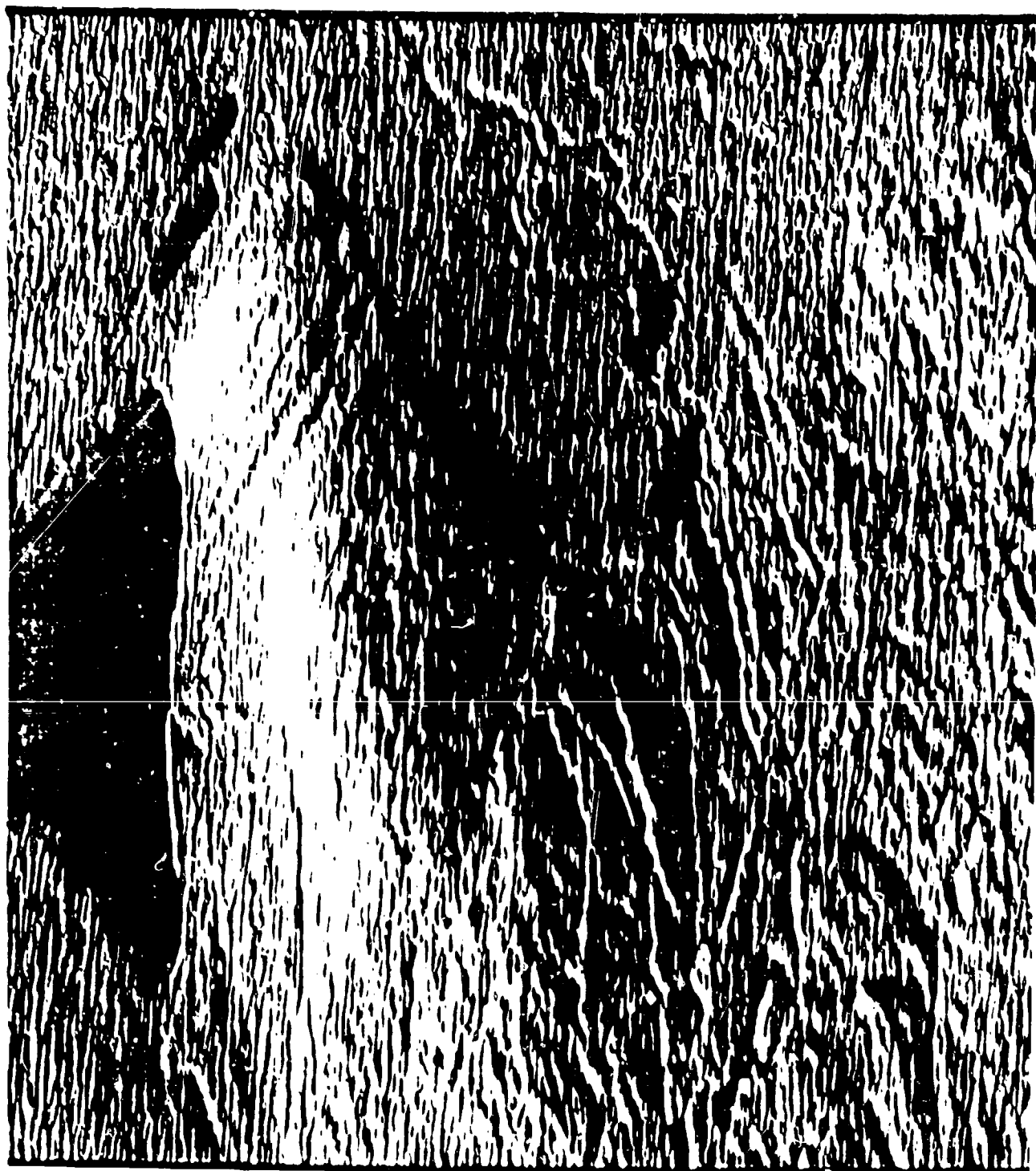
Fig. 10 Shaded Relief – Area 1 – Modified Data
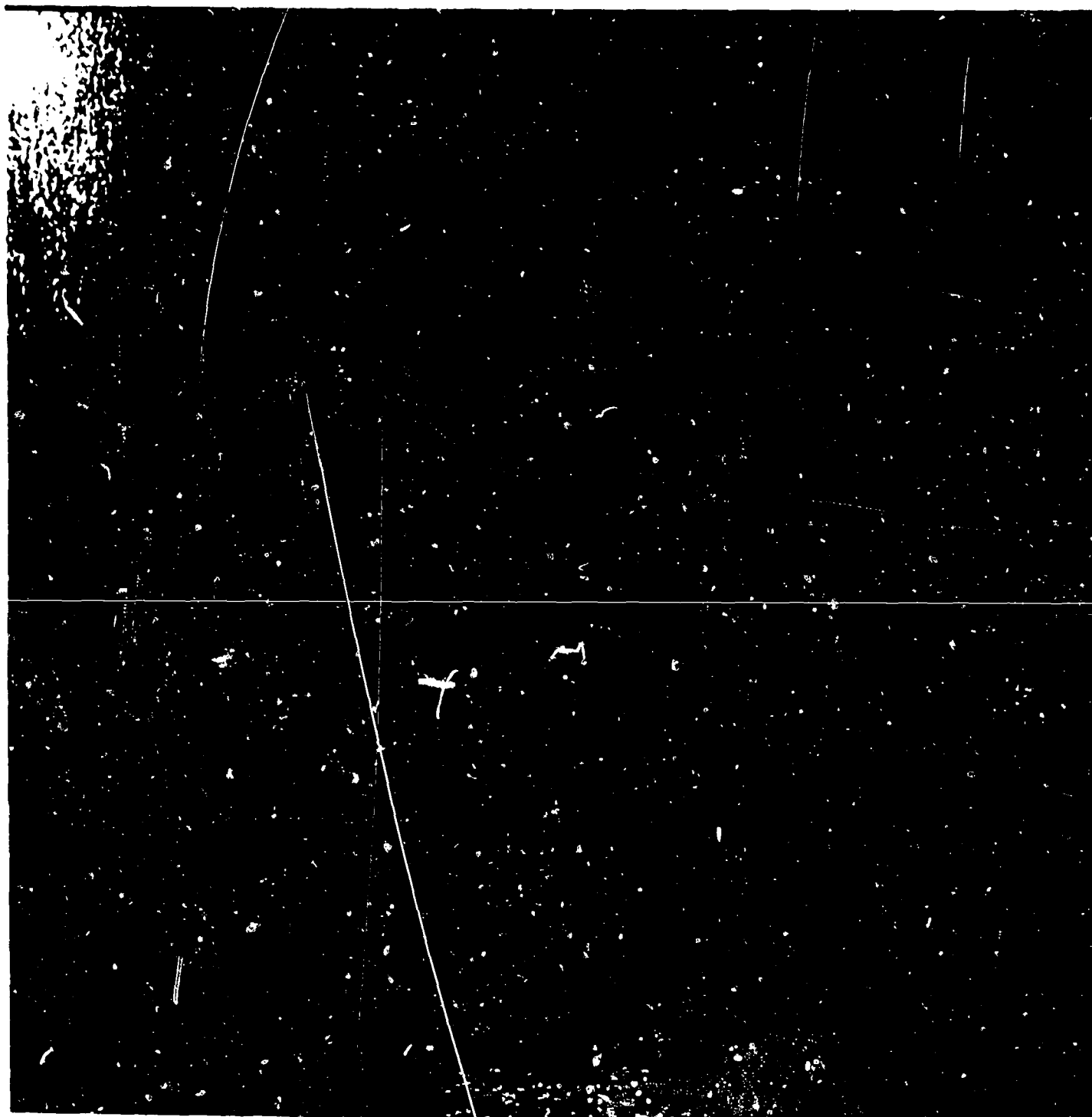
Fig. 11 Linear Spectrum – Area 1 – Modified Data
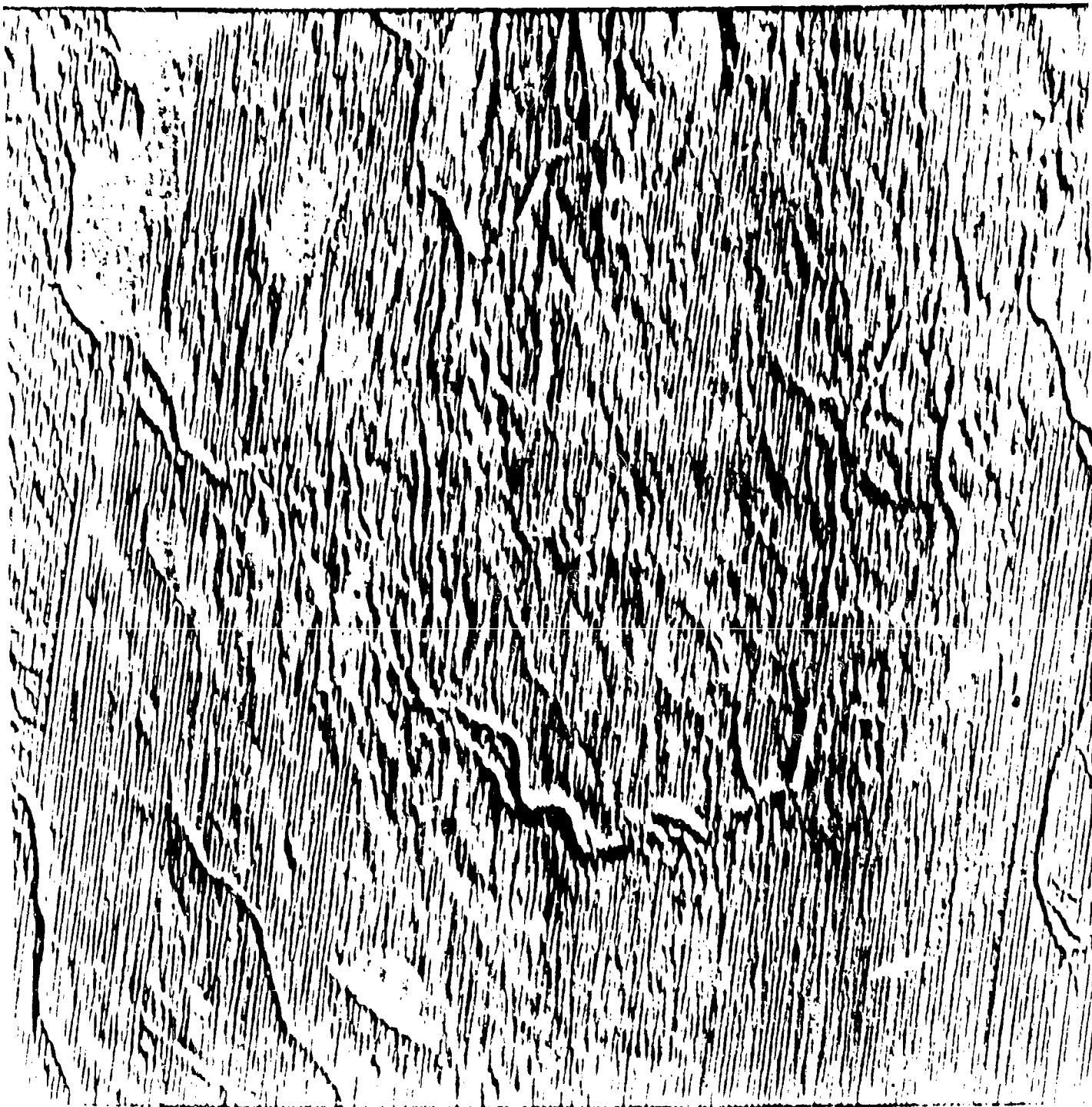
Fig. 12 Shaded Relief - Area 2 - Original Data
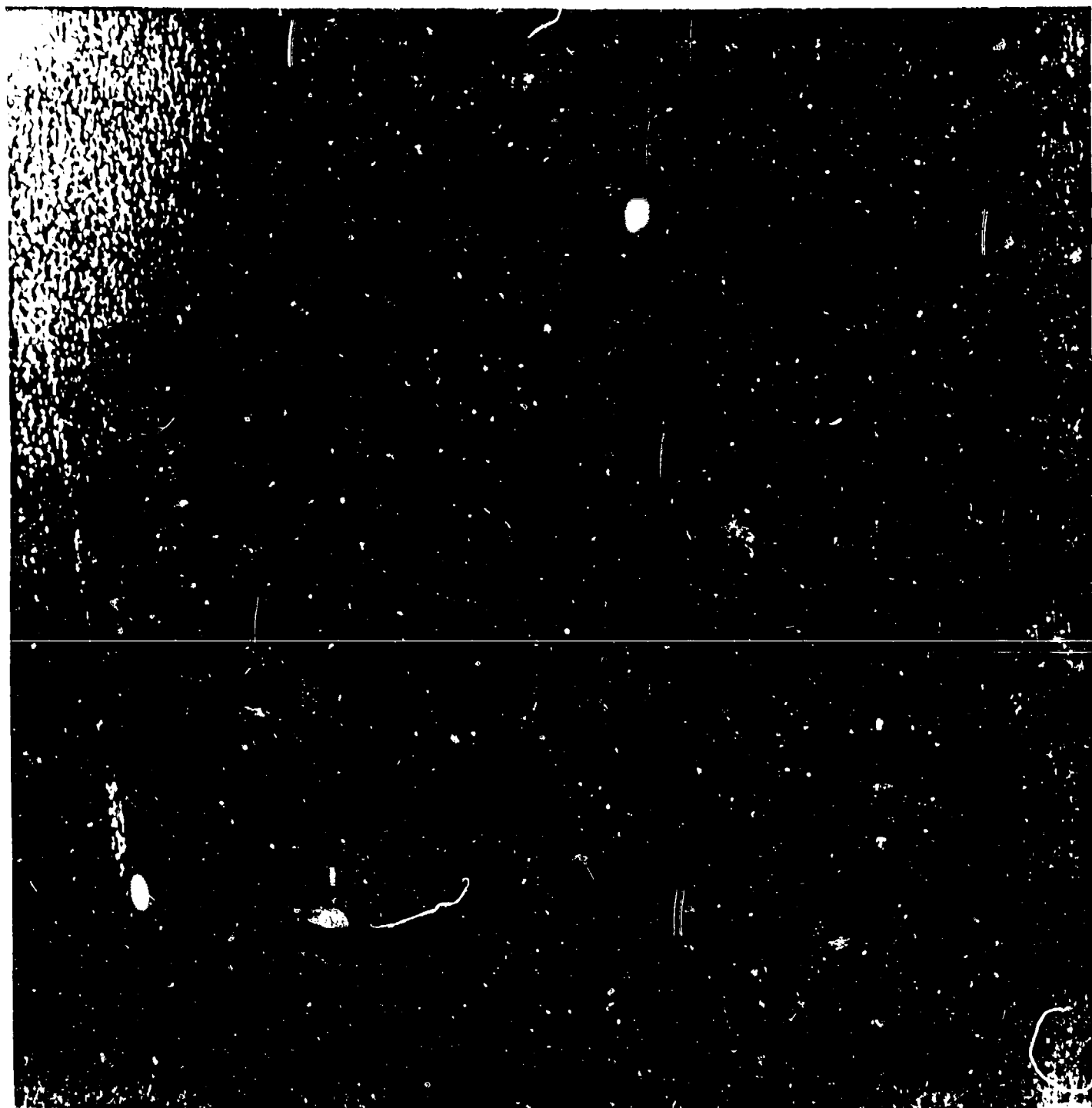
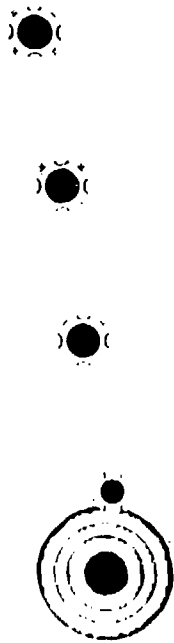Fig. 13 Linear Spectrum – Area 2 – Original Data
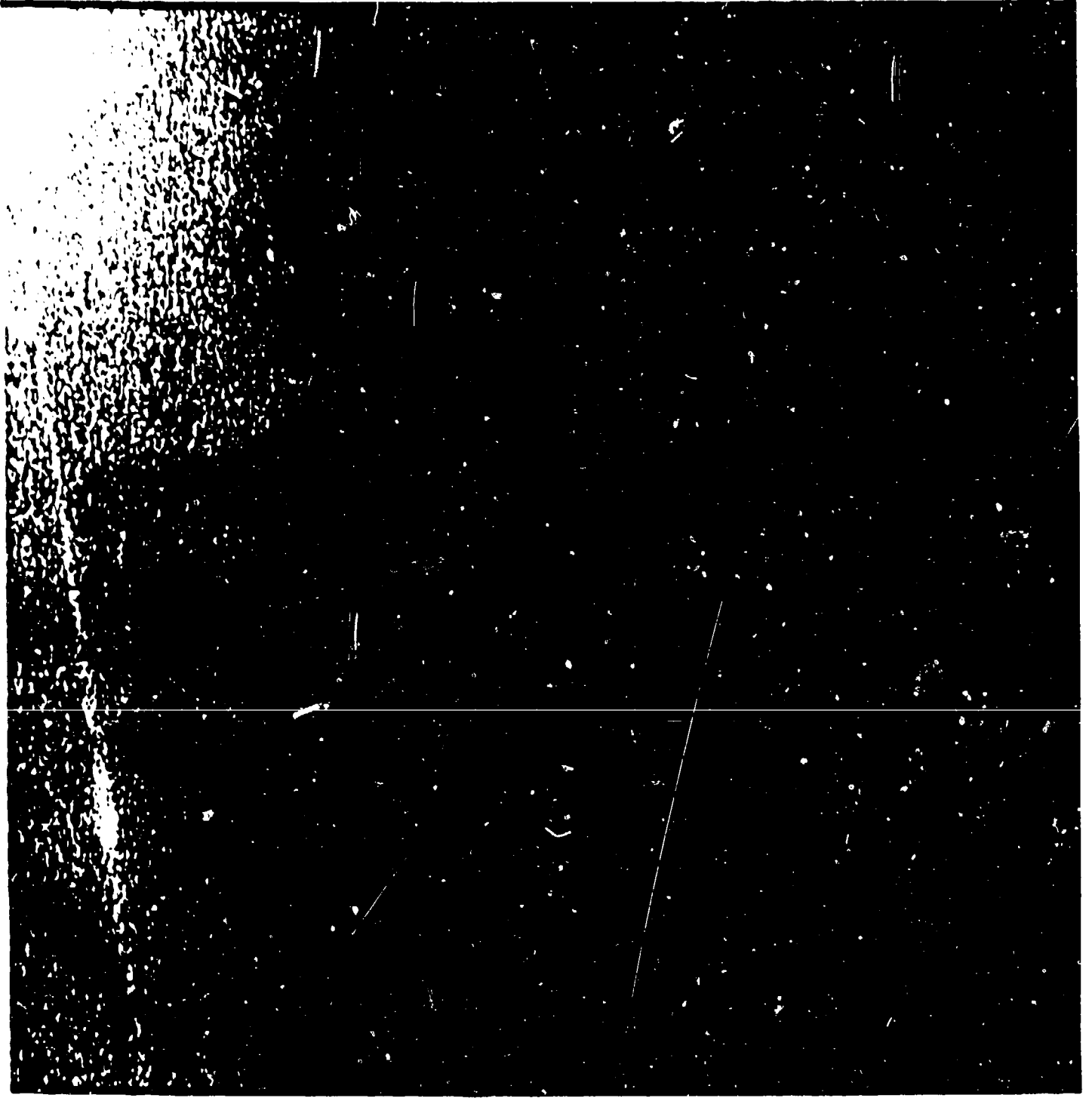
Fig. 14 Log Spectrum – Area 2 – Original Data
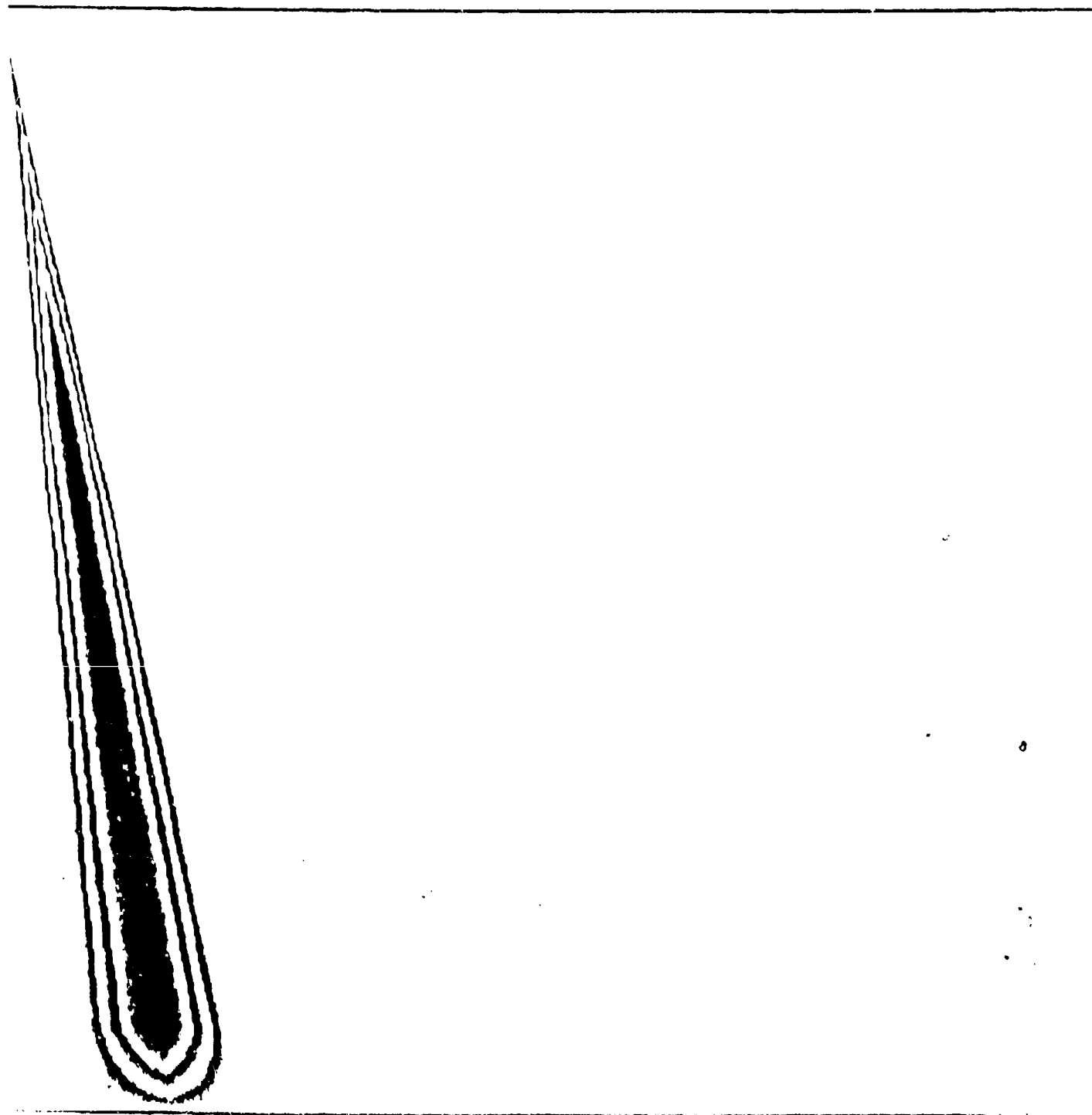
Fig. 15 ± 4° Fan-reject Filter
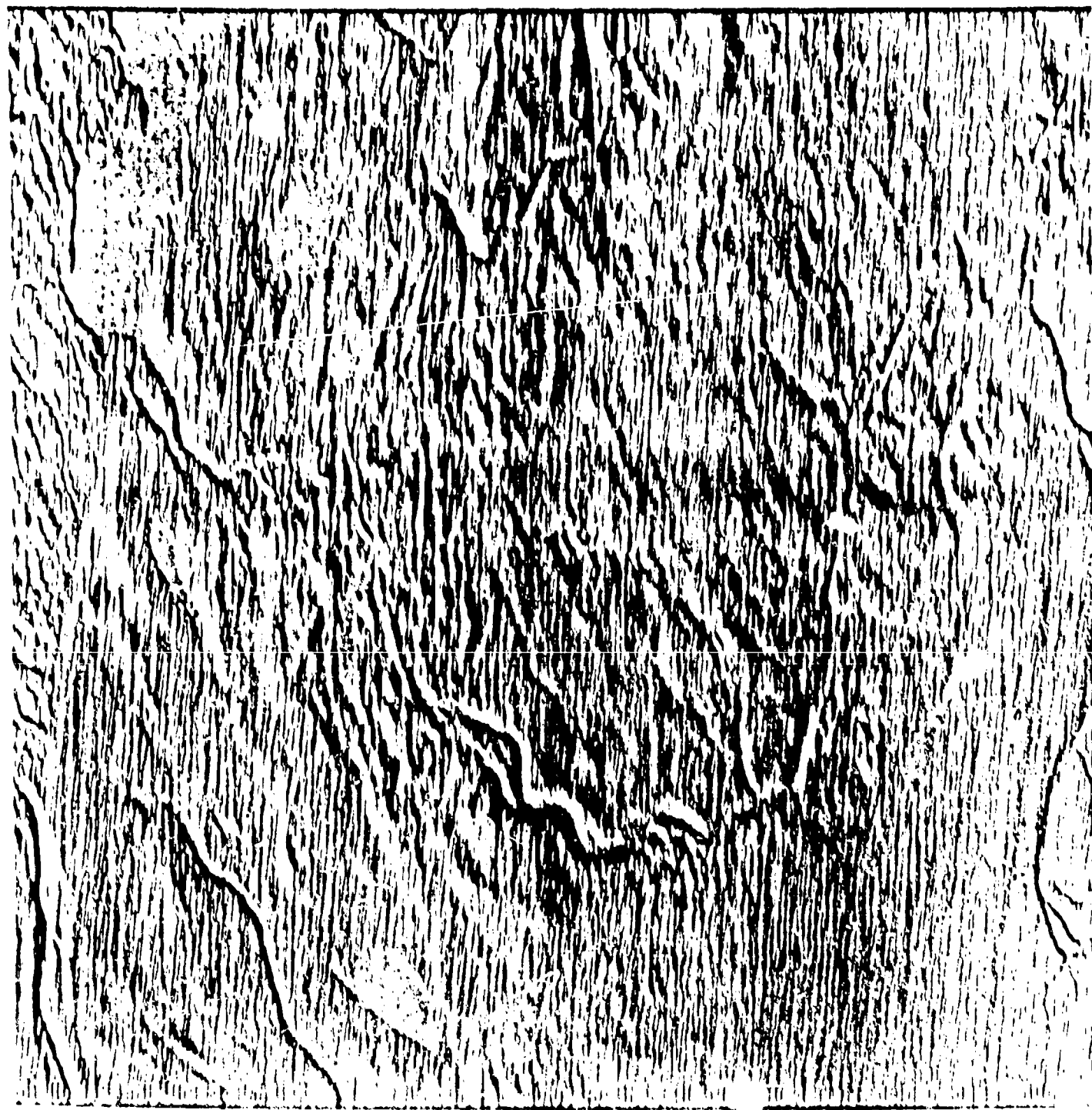
Fig. 16   Shaded Relief - Area 2 - Modified Data
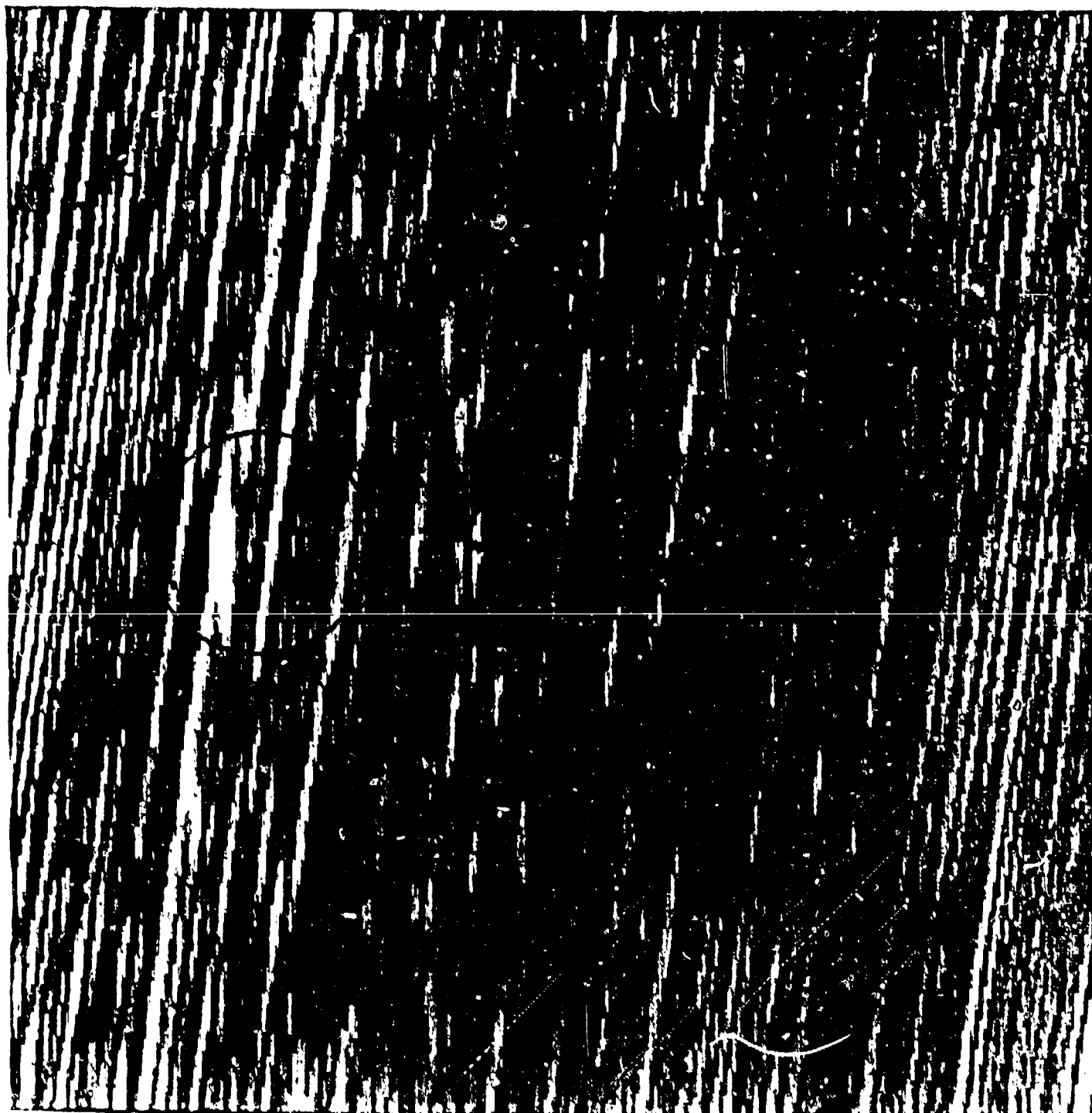
Fig. 17 Grey Level Difference - X2 Zoom

Fig. 18 Shaded Relief - Area 2 - Original / Modified

Fig. 19   Shaded Relief – Area 2 – 3 × 3 Smoothed Data

Fig. 20 Shaded Relief – Area 2 – 5 X 5 Smoothed Data
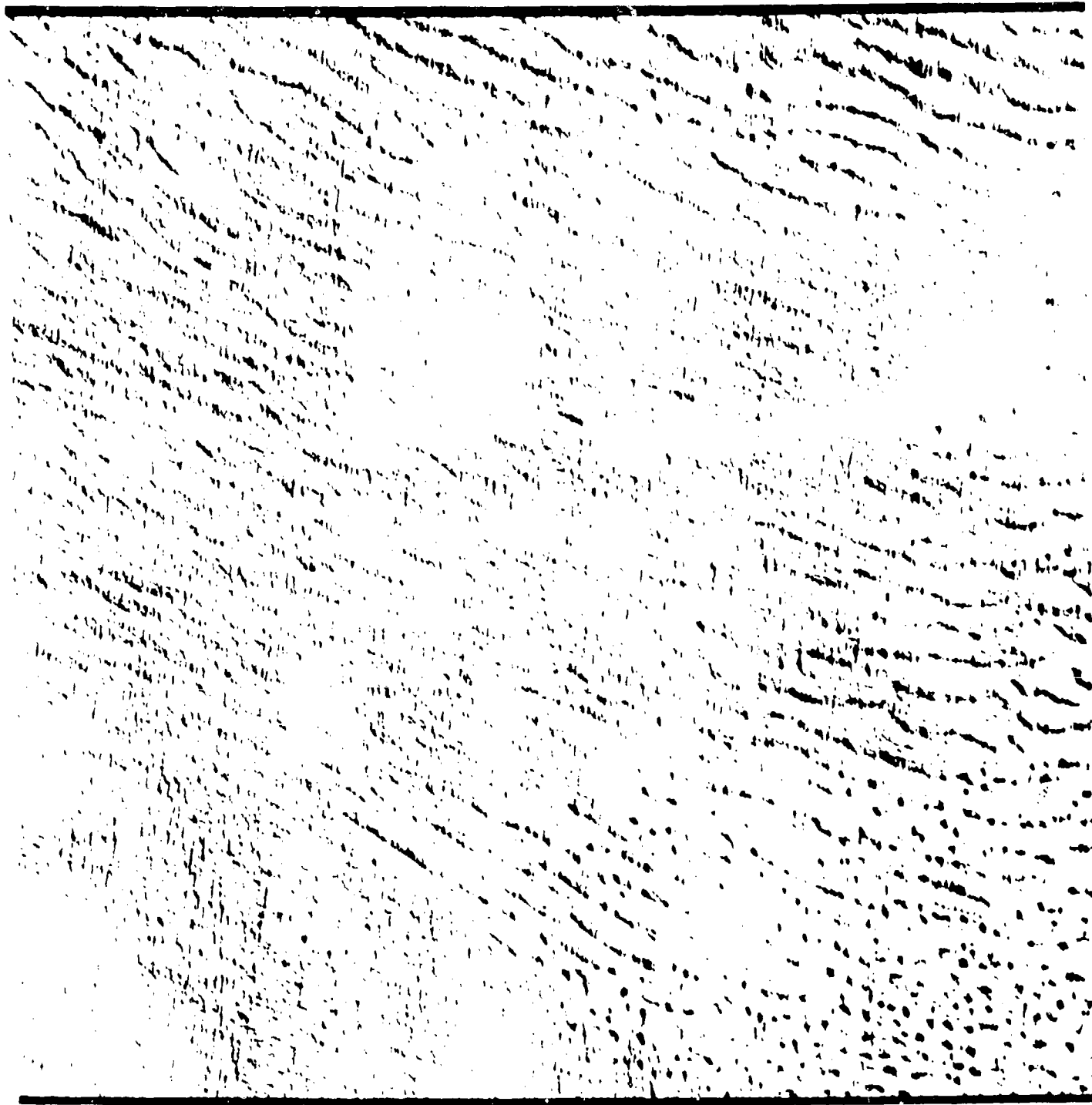
Fig. 21 Shaded Relief – Area 3 – Original Data

Fig. 22 Linear Spectrum – Area 3 – Original Data
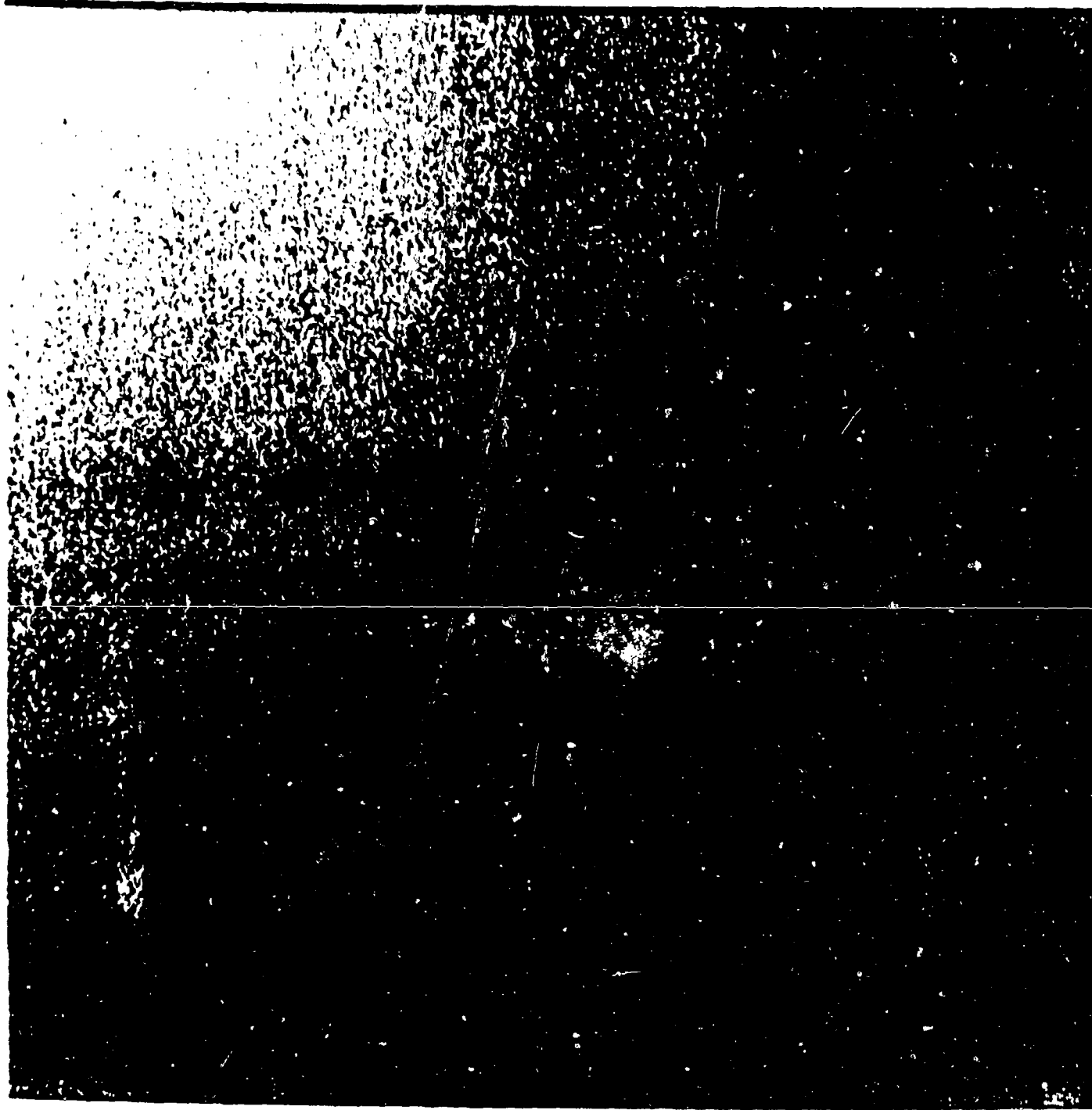
Fig. 23 Log Spectrum – Area 3 – Original Data
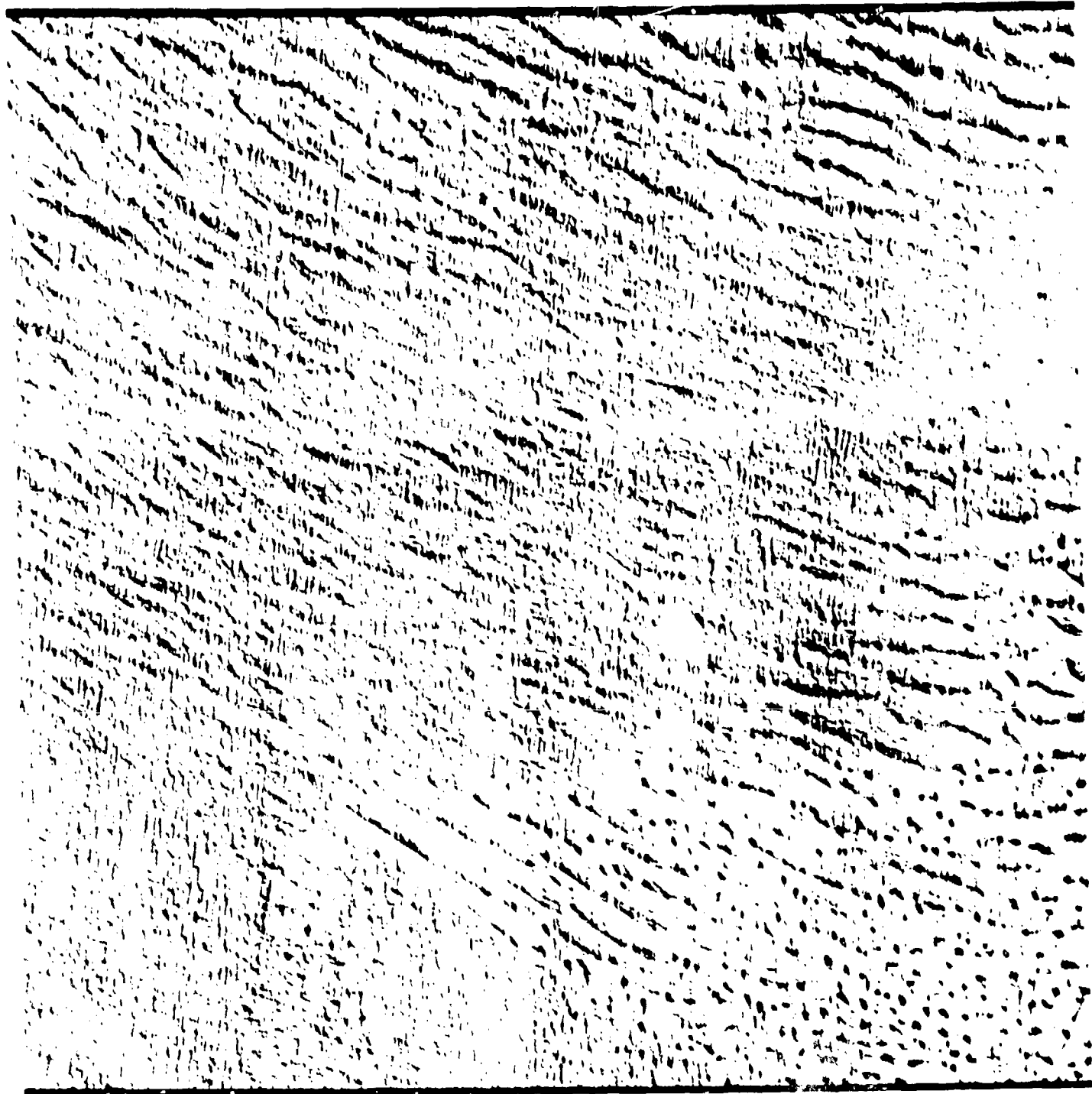
Fig. 24 Exponential Band-reject Filters

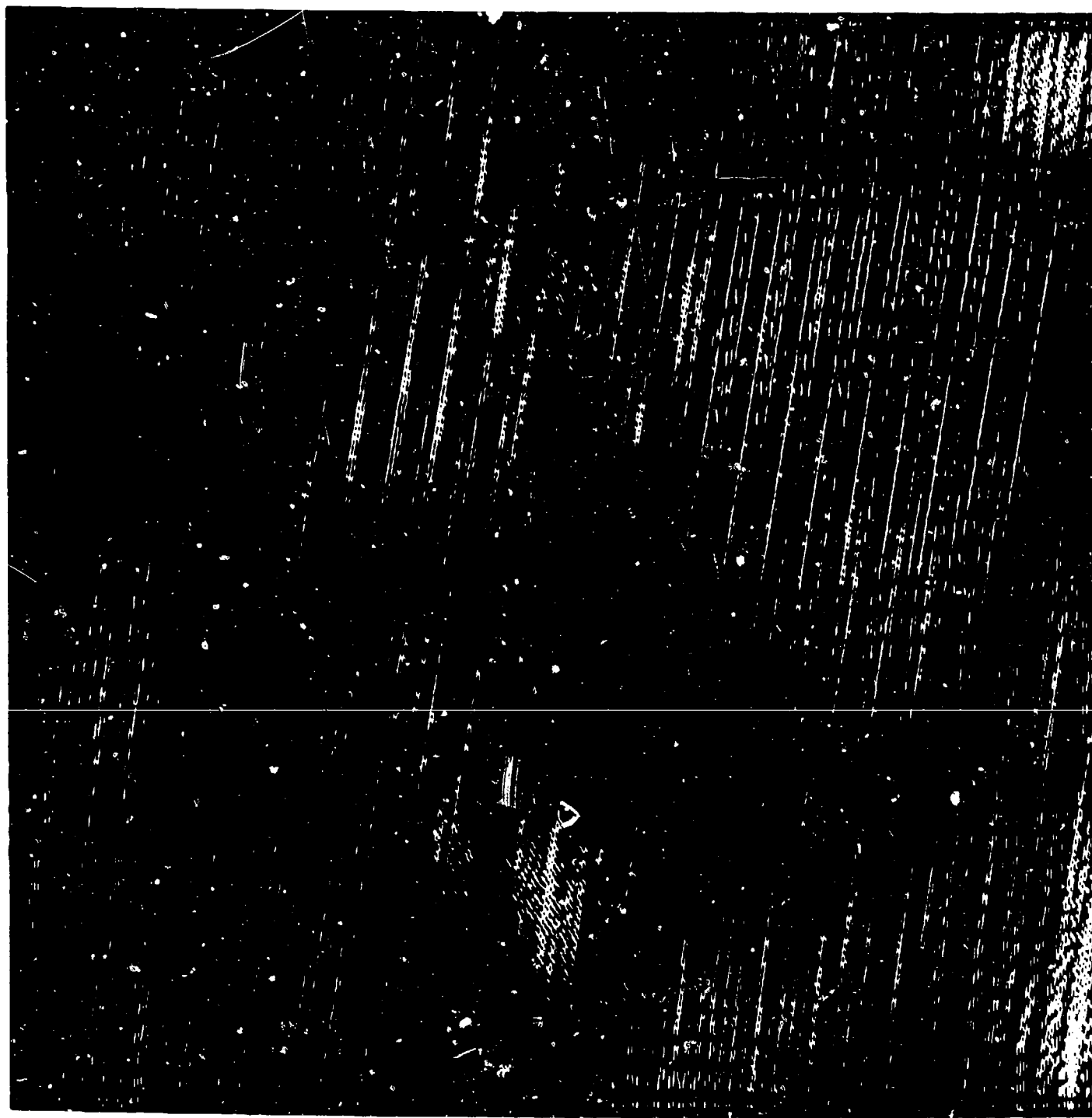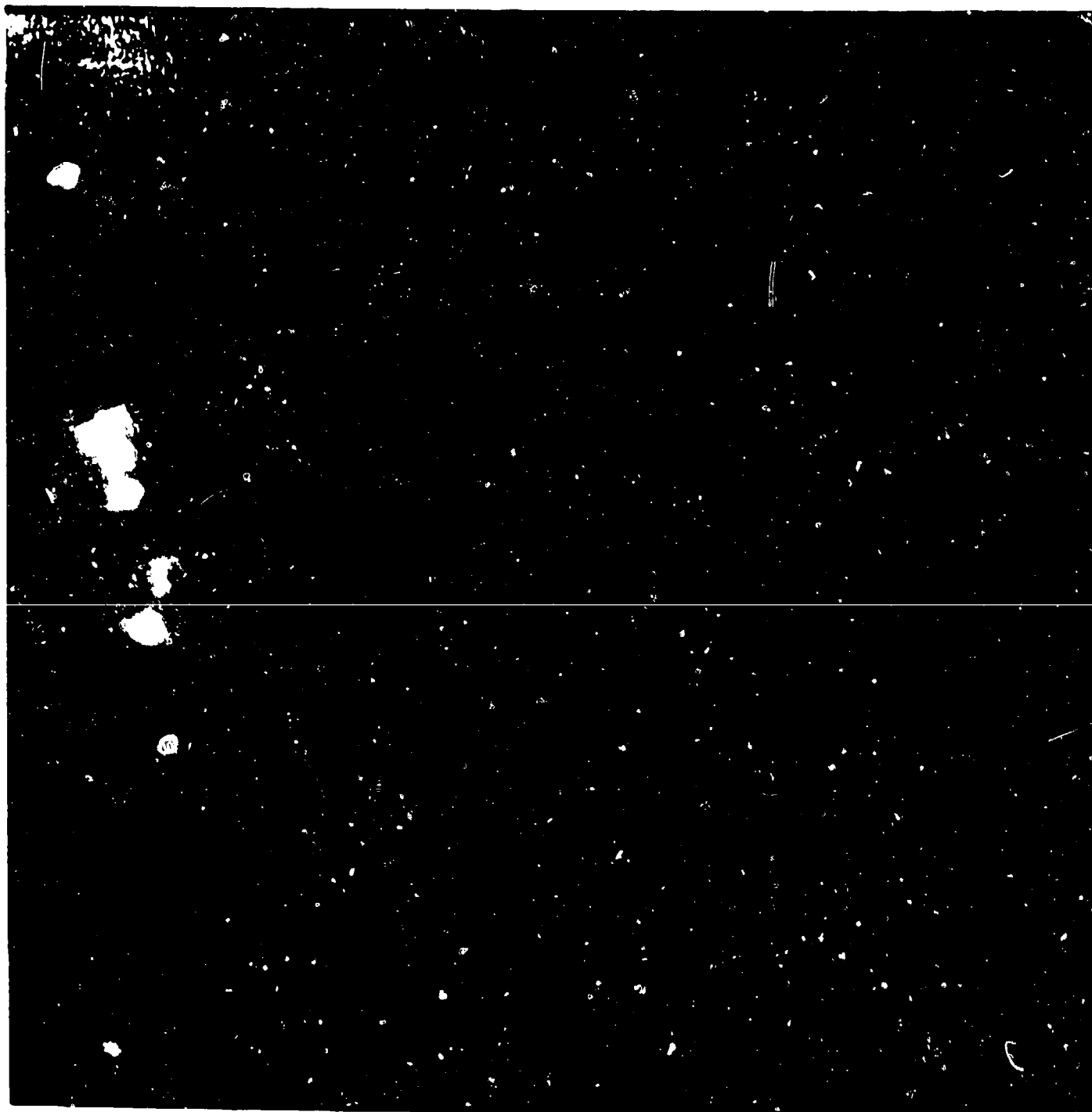Fig. 25 Shaded Relief - Area 3 - Modified Data

Fig. 26 Grey Level Difference

Fig. 27 Linear Spectrum – Area 3 - Original Data